e-Manufacturing Solutions

Additive Manufacturing (Industrial 3D Printing) Applications in Aerospace

2017 Siemens PLM Software Greater China User Conference

1st ~ 3rd March, Wuhan

Jiaru Lu 陆嘉儒

Area Sales Manager – Greater China

EOS GmbH

Agenda

e-Manufacturing Solutions

- **EOS – Leader in e-Manufacturing Solutions**
- Additive Manufacturing: “The Manufacturing Technology that will Change the World”
- Additive Manufacturing for Aerospace
- Summary

More than 25 years in Additive Manufacturing

EOS HQ in Krailling, Germany

EOS: Technology and market leader for design-driven, integrated e-Manufacturing Solutions

e-Manufacturing Solutions

- Family-owned, founded in 1989 by Dr. Hans Langer
- Focus on end-to-end Solutions for Additive Manufacturing: from part design and data generation to part building and post-processing
- Active in a variety of industries, focus on medical, aerospace, industrial applications
- EOS is committed to: Innovation – Quality – Sustainability
- Revenue FY 15/16: ~ 315 Mio €
- Revenue Increase to FY 14/15: ~ 20%

Dr. Adrian Keppler, Eric Paffrath, Dr. Hans J. Langer, Dr. Tobias Abeln (from left to right)

EOS Headquarters in Krailling, Germany

Global presence: we are, where you need us

e-Manufacturing Solutions

almost
1,000 Employees

EOS
Sales & Service
offices in
11 countries

67 distributor
offices
worldwide

2,400
EOS systems
installed
worldwide

40%
Metal systems

60%
Polymer systems

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e-Manufacturing Solutions

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We are experts
in plastic and metal AM technology …

EOS Additive Manufacturing: SLS/SLM Functional Principle

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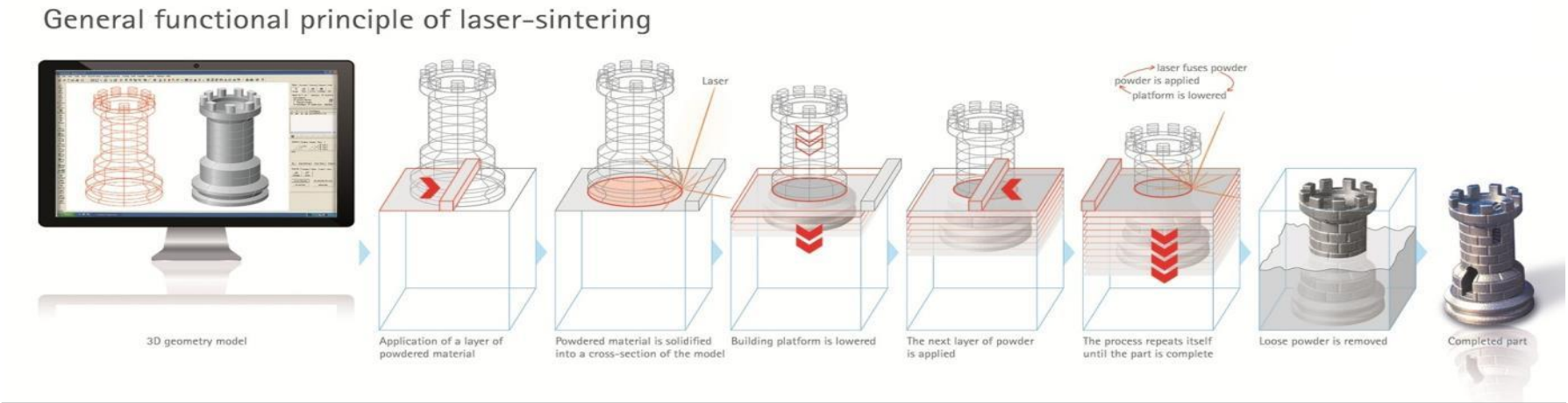
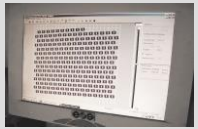
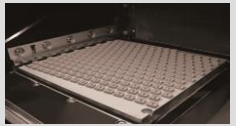




From a 3D CAD model…

- Application of powder
- Exposure by Laser

- Lowering of platform
- Re-application of powder
- Exposure by laser



… to complete parts

Functional principle for polymer and metal materials. Source: EOS

Advantages of Laser Sintering

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Laser Sintering offers various advantages compared to traditional manufacturing processes

Freedom of design

Lightweight
- Static: weight of parts
- Dynamic: moving, accelerated parts

Complex components
- E.g. alternative structures of heat exchangers

Cost advantage

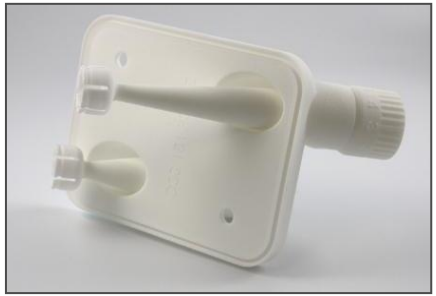
Integrated functionality
- Embedded functionality without assembly
- Material efficiency
- No tooling cost

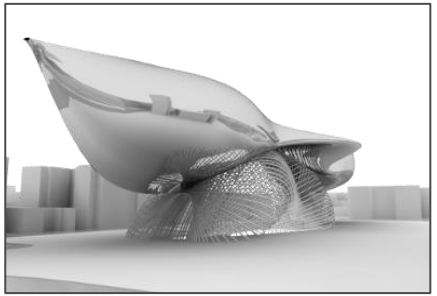
Customisation

Individualised parts
- Customer specific adaptations
- Cost efficient small series up to 'lot size one'

Time to market

Rapid prototyping
- Fast feasibility feedback of virtual models
- Haptic feedback





EOS Mission

Provide industrial grade AM **SYSTEM**, **MATERIALS**, **PROCESS** & **SERVICES**.

Polymer Laser Sintering systems

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FORMIGA P 110

Compact system for small and medium sized parts with best detail resolution

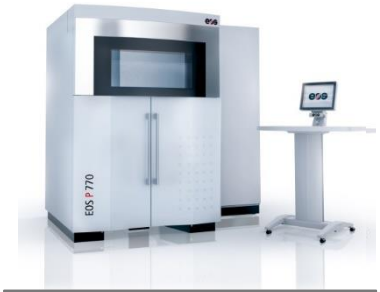
Usable build size
200x250x330 mm

EOS P 396

Fastest polymer laser sintering system in the world! Effectively isotropic part properties.

Usable build size
340x340x600 mm

EOS P 770



Double-head system for high throughput production and/ or large parts.

Usable build size
700x380x580 mm

EOSINT P 800

For high-performance polymer parts.

Usable build size
700x380x560 mm

Production scale

SMALL SERIES | FLEXIBLE | LARGE SERIES | LARGE Specialised SERIES

Direct Metal Laser Sintering systems

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EOS M 100

Proven DMLS quality for small-scale production

Build volume:
Ø 100 mm x 95* mm

Laser: 200 W Yb-fiber, focus diameter 40 µm

EOS M 290

Proven DMLS quality with enhanced quality management

Build volume (wxdxh):
250 x 250 x 325* mm

Laser: 400 W Yb-fiber laser, focus diameter 100 µm

EOS M 400

Proven DMLS Quality for the production of large parts

Build volume (wxdxh):
400 x 400 x 400* mm

Laser: 1000 W Yb-fiber, focus diameter 90 µm

EOS M 400-4

Proven DMLS Quality with up to 4x higher productivity

Build volume (wxdxh):
400 x 400 x 400* mm

Laser: 4x 400W Yb-fiber, focus diameter 100 µm

SMALL FRAME | MEDIUM FRAME | LARGE FRAME

Polymer high quality materials

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15 materials: the largest OEM-portfolio of Laser Sintering materials

Family	Material name
PA 12 unfilled	PA 2200
	PA 2201
	PrimePart® PLUS (PA 2221)
PA 12 colored	PA 2202 black
	PA 2105 (gum colored)
PA 12-GB	PA 3200 GF
PA 12-AL	Alumide®
PA 12-CF	CarbonMide®
PA 12-FR	PA 2210 FR
	PrimePart® FR (PA 2241 FR)
PA 11 unfilled	PA 1101
PA 11 black	PA 1102 black
Elastomer (TPE)	PrimePart® ST
Polystyrene (PS)	PrimeCast® 101
Polyaryletherketone (PAEK)	EOS PEEK HP3

Metal high quality materials

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Currently over 16 powder alloys with more in development

Family	Metal Alloy
Aluminium	EOS Aluminum AlSi10Mg
Cobalt Chrome	EOS CobaltChrome MP1
	EOS CobaltChrome RPD
	EOS CobaltChrome SP2
Maraging Steel	EOS MaragingSteel MS1
Nickel Alloy	EOS NickelAlloy HX
	EOS NickelAlloy IN625
	EOS NickelAlloy IN718
Stainless Steel	EOS StainlessSteel 17-4PH
	EOS StainlessSteel 316L
	EOS StainlessSteel CX
	EOS StainlessSteel GP1
	EOS StainlessSteel PH1
Titanium	EOS Titanium Ti64
	EOS Titanium Ti64ELI
	EOS Titanium TiCP Grade 2

EOS excellent processing program

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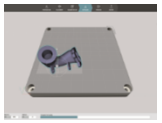
High quality materials		Variety of quality approved materials
Validated EOS processes		Validated processes for excellent part quality from the start
Process development tools		Open process development environment
System & Process monitoring		Integrated monitoring suite

Ensuring reliable part quality.

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Aerospace – Jet Engine

- GE
- Pratt & Whitney
- Rolls Royce
- AVIO
- Snecma
- Turbomeca
- Klimov
- MTU
- Engine Alliance

SOURCE: EOS

CFM LEAP engine

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Source: CFM International

We see big OEMs to start setting up production

Example General Electric Aviation

- 19 fuel nozzles to be installed on every CFM LEAP engine (more than 4500 sold)
- 100.000 additive parts will be manufactured by GE Aviation by 2020
- 1.000 lbs potential reduction in weight of a single aircraft engine through additive production
- 300 plus 3D printing machines currently in use across GE

David Joyce
president and CEO

Source: Morris Technologies, General Electric

RUAG Satellite Bracket - Optimization

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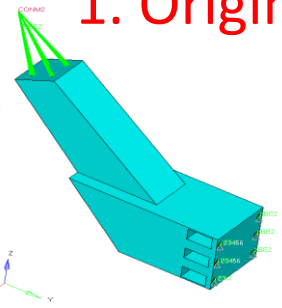
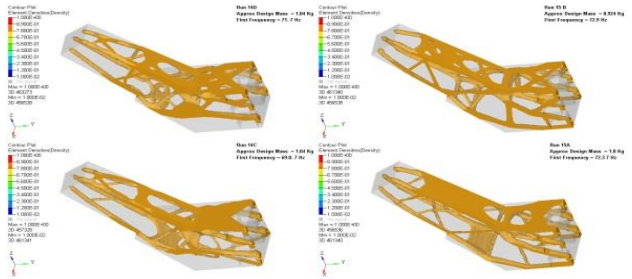
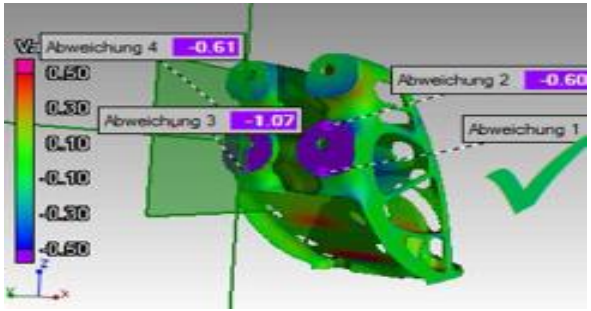
1. Original Design



2. Topology optimization



3. FEM Analyse



4. New Design

RUAG Satellite Bracket – Build Part

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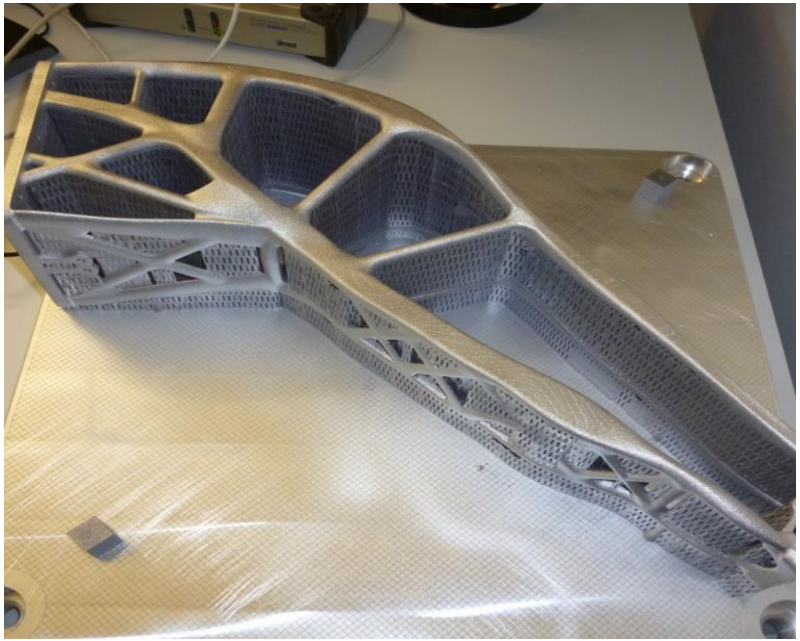
New Bionic Design : Build with EOS M400 and EOS Aluminium AlSi10Mg

Two parts in one job, with 1kW laser power in 41 hours



-30 %

-50 %

-40 % weight

Project : RUAG

Door hinge build with DMLS

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Challenge

- Create a "light weight" nacelle hinge

Solution

- Stress and load path proved design by EADS engineers
- Highly complex design built as "one piece" with integrated function
- Built on M270 Xt
- Material: Ti64

Benefits

- A 60% weight saving was achieved through topology optimization
- Significant cost reduction

Optimized A320 Nacelle Hinge – DMLS and Conventional EOS Ti64 produced on EOSINT M 270Xt at EADS IW

Source: Evo Maganize and EADS IW Filton, from:
http://www.evo.co.uk/features/features/261526/3d_printing_is_this_the_future.html

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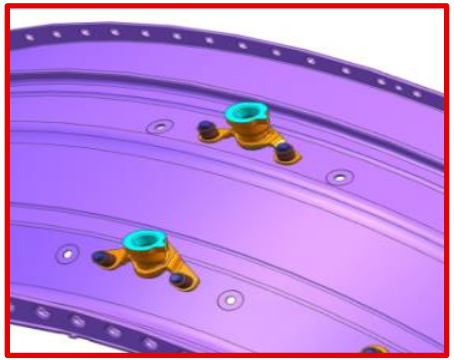
First AM production parts

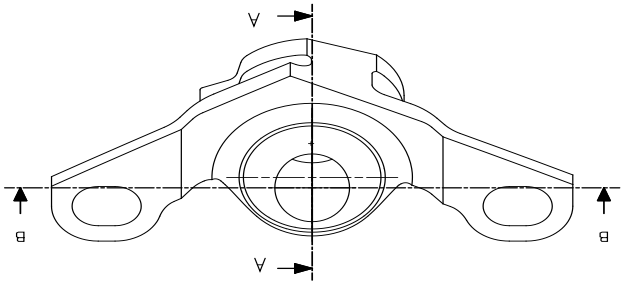
Boroscope bosses for the A320NEO engine finally brought in production

All development engines provided with AM parts

Start of production in 2013

Ramp-up in 2015





UK - production with EOS AM Technology

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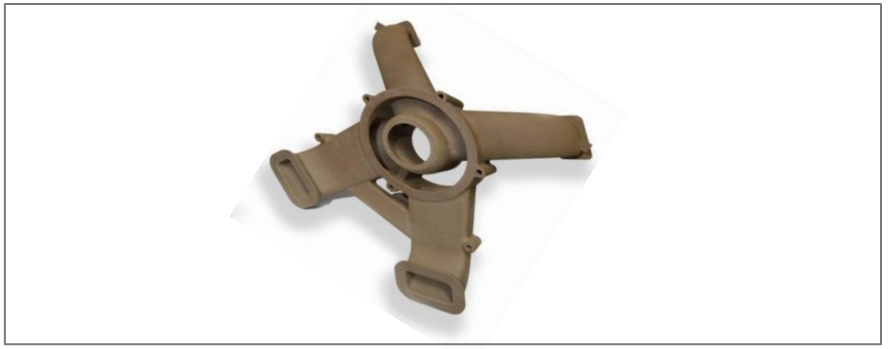
- **Delivered up to date about to 6,000 parts**

Source: Materials Solutions

EOSINT P 800 with EOS PEEK HP3

HP3 – high-temperature and performance Applications

- Material belong to the Polyaryletherketone Group
- Outstanding material data:
  - Tensile strength up to 95 MPa
  - Youngs modulus up to 4400 MPa
  - Long term usability between 180 °C and 260 °C
- Exceptional performance:
  - High chemical resistance
  - Flame retardant conform UL 94- V0
  - Biocompatibility
  - Sterilisability



Source: EOS GmbH, FP

Aerospace Ducting additively manufactured with polymer

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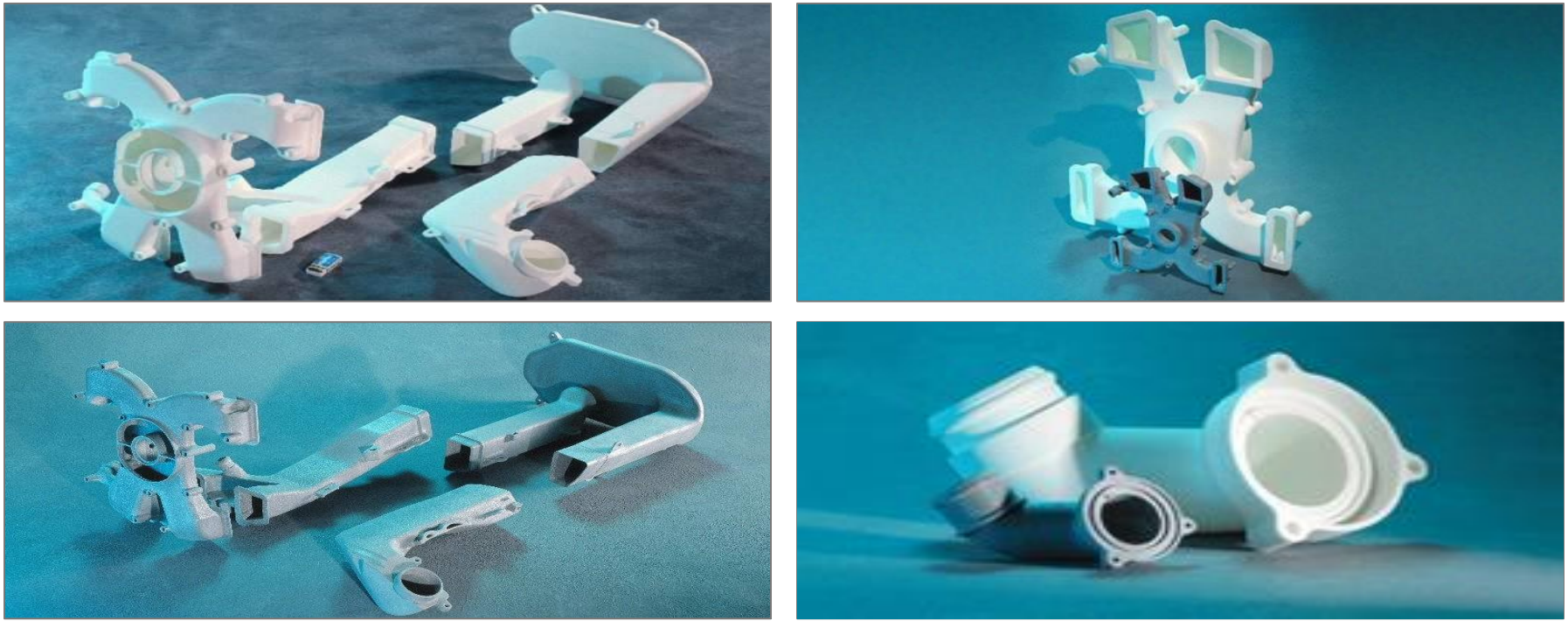

Source: EOS GmbH

New – Flame Retardant Materials

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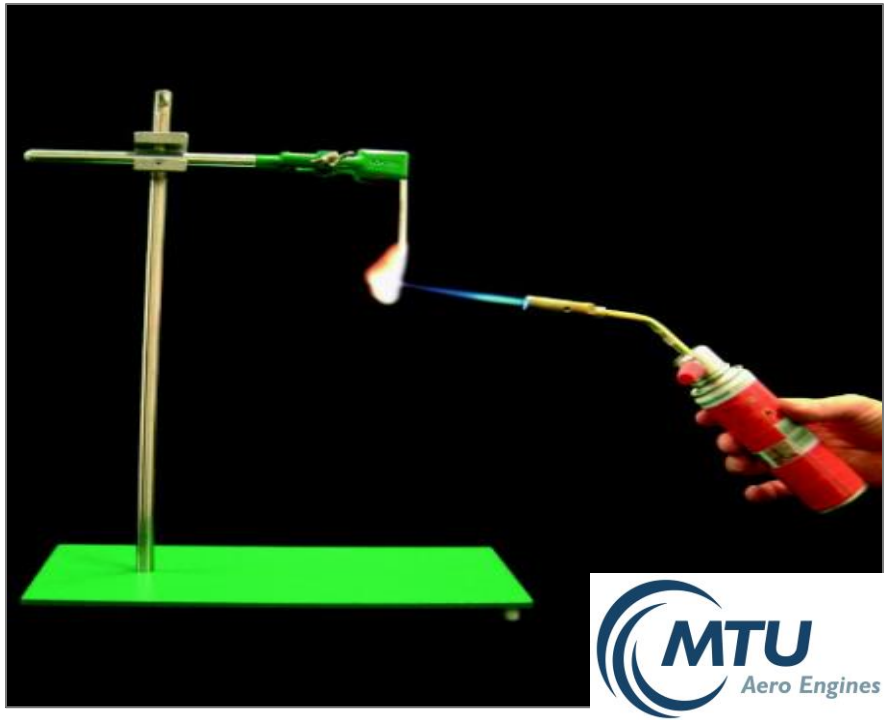
Materials for e-Manufacturing

- PA 2210 FR/PA 2241 FR
  - UL 94 V0 confirmed
  - FAR/JAR qualification
  - Tested on:
    - Flammability
    - Smoke Density
    - Smoke Toxicity
    - Heat Release
- New temperature areas
- Improved material properties



Source: EOS GmbH

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GE Aviation set up a 300.000 sqft AM facility

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Source: http://triblive.com/business/headlines/10235278-74/manufacturing-center-additive

Siemens invested €21.4 m into its AM facility

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Image Courtesy of Siemens

Together, we shape the future of manufacturing!